U.S. Department of Transportation

FEDERAL AVIATION ADMINISTRATION

Airplane Fuel Efficiency Certification
Notice of Proposed Rulemaking

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Executive Summary

The Federal Aviation Administration (FAA) is proposing regulations necessary to implement new airplane emissions standards in the certification process. This document provides analysis of the benefits and cost of the proposed rule.

Background and Summary of Regulation

In 2017, the International Civil Aviation Organization (ICAO), with significant participation by the FAA and the U.S. Environmental Protection Agency (EPA), adopted standards for carbon dioxide (CO_2) emissions from airplanes. Under the Chicago Convention, the United States must adopt standards into law that are at least as stringent as those adopted by ICAO. The EPA has authority under the Clean Air Act (CAA) to set standards for emissions from aircraft engines and the FAA has authority to enforce those standards, which it does at the time of aircraft design approval (type certification). Accordingly, both the FAA and the EPA are responsible for domestic adoption of the ICAO standards.

The ICAO standards took effect for adopting member States beginning on January 1, 2020 for new type designs (January 1, 2023 for smaller airplanes). On January 11, 2021, the EPA promulgated greenhouse gas emission standards for airplanes that match the ICAO standards. Under the CAA, the FAA now has responsibility to enforce the standards at the time of aircraft certification. Therefore, the FAA is proposing to adopt the standards in order to certificate applicable airplanes as compliant. The proposed regulation would require that airplane manufacturers meet prescribed limits for airplane fuel efficiency measured using a metric value expressed in units of kilograms of fuel consumed per kilometer.

Baseline for the Analysis

The baseline for analysis of the incremental costs and benefits of the proposed rule includes the existing regulations and current capabilities of U.S. aircraft manufacturers to meet the ICAO standards, and the environmental risks associated with aircraft emissions. The ICAO traditionally sets standards that are technology-following standards, meaning that the CO_2 standards reflect a level of emissions performance already achieved by some percentage of current in-production airplanes. The EPA also conducted its own study and concluded that aircraft currently produced will meet the ICAO standards in the absence of U.S. regulations (EPA, 2020). The FAA identified three U.S. manufacturers that would be affected by the proposed rule.

In 2016, the EPA found that elevated concentrations of greenhouse gases in the atmosphere endanger the public health and welfare of current and future generations (81 FR 54422). The EPA made this finding with respect to six well mixed greenhouse gases, including CO_2, that together constitute the primary cause of climate change. The EPA also found that emissions of these gases from certain classes of engines used in certain aircraft are contributing to the air pollution that endangers public health and welfare. Public health risks include the risk of premature morbidity from local air pollution (primary and secondary particulate matter concentrations).

Benefits

The analyses conducted by the ICAO, with FAA participation, indicate that compliance with the airplane CO_2 emissions standards will generate climate change and air quality (human health) benefits globally, including in the United States (ICAO 2016a; 2016b). These benefits will be achieved in the baseline, since manufacturers – who operate in a global marketplace – will need to certificate to the ICAO standards even in the absence of a proposed domestic rule. Manufacturers did not identify incremental environmental and human health benefits associated with the proposed rule.

Costs

Certification tasks will vary greatly depending on the stage of the airplane development process (e.g., new type certificate, supplemental type certificate). Additionally, initial certifications may be more involved than subsequent ones due to process familiarity and the ability to reuse data. To estimate these costs, the FAA used information provided by the affected airplane manufacturers to construct a timeline of when these costs would be incurred over the next 10-years (starting in 2022). The FAA calculated both baseline costs and incremental costs attributable to the proposed rule aggregated across the manufacturers.

In the absence of the proposed rule, manufacturers would need to conduct the certification activity through foreign certificating authorities. Airplane manufacturers' estimates of the impact of such circumstances on costs vary and reflect as yet unknowns, but suggest annualized incremental costs of $0.4 million using discount rates of 3 percent and 7 percent. The present value over 10 years would be $3.1 million using a 3 percent discount rate and $2.6 million using a 7 percent discount rate. The proposed rule avoids these incremental certification costs thus generating cost savings (Table 2).

Table 1. Incremental Impact of Proposed Rule (Millions 2020$)[1]

Annualized Costs (3% Discount Rate)	Present Value over 10 Years (3% Discount Rate)	Annualized Costs (7% Discount Rate)	Present Value over 10 Years (7% Discount Rate)
-$0.4	-$3.1	-$0.4	-$2.6

1. Represents the avoided costs of certifying to the ICAO airplane CO_2 emissions standards through foreign certification authorities compared to through the FAA under the proposed rule.

Comparison of Benefits and Costs

Because the EPA standards apply even in the absence of the proposed rule, there are not incremental benefits of associated with the FAA's action. However, the proposed rule will result in cost savings through enabling U.S. manufacturers to certificate to the standards domestically. Annualized costs savings would be approximately $0.4 million using discount rates of 3 percent discount and 7 percent (a present value over 10 years of $3.1 million using a 3 percent discount rate and $2.6 million using a 7 percent discount rate).

There are a number of uncertainties associated with these results. With respect to benefits, there is potential for greater fuel efficiency gains as a competitive advantage for manufacturers. At the same time, the impact of the public health emergency concerning the novel coronavirus disease (COVID-19) on the industry is uncertain. Changes in airplane fleets could affect the estimated baseline, as well as benefits and costs. The timing for rule implementation may also be an important factor in that market demand may speed up manufacturers' schedules for certification to meet the original applicability dates in the ICAO standard.

1.0 Introduction

The Federal Aviation Administration (FAA) is proposing regulations necessary to implement new airplane emissions standards in the certification process. This document provides the FAA's analysis of the impact of this regulatory change.

1.1 Background

The United States is a signatory to the Chicago Convention[1] which set forth the core principles permitting international air transportation. The Chicago Convention led to the creation of the International Civil Aviation Organization (ICAO) with the purpose of helping member States achieve uniformity in civil aviation standards, policies, and procedures. ICAO manages over 12,000 global Standards and Recommended Practices (SARPs) across 19 Annexes to the Chicago Convention (ICAO, 2019). The United States participates in developing these global standards and practices to ensure safety and security in aviation, and achieve efficient business operations in a market economy.

In 2017, ICAO, with significant participation by the FAA and the U.S. Environmental Protection Agency (EPA),[2] adopted standards for carbon dioxide (CO_2) emissions from airplanes. The CO_2 standards are whole-airplane fuel efficiency performance standards, rather than the typical single pollutant engine emissions standards. The Chicago Convention obligates the United States to adopt standards into law that are at least as stringent as those adopted by ICAO. The EPA has authority under the Clean Air Act (CAA) to set standards for emissions from aircraft engines and the FAA has authority to enforce those standards, which it does at the time of aircraft design approval (type certification). Accordingly, both the FAA and the EPA are responsible for domestic adoption of the ICAO standards.

The ICAO standards took effect for adopting states beginning on January 1, 2020, for new type designs (January 1, 2023 for smaller airplanes). In January 2021, EPA standards for greenhouse gas emissions that apply to airplanes used in commercial aviation and large business jets took effect [40 Code of Federal Regulations (CFR) parts 87 and 1030]. These standards match the airplane CO_2 standards adopted by the ICAO. Under the CAA, the FAA has responsibility to enforce the standards at the time of aircraft certification. Therefore, the FAA is proposing regulations to enforce those standards at the time of certification to meet the international standards and maintain the global competitiveness of U.S. manufacturers.

1.2 Summary of the Regulation

The proposed regulation would require that certain airplanes, identified in 14 CFR §38.1, meet prescribed limits for CO_2 emissions measured using a fuel efficiency metric (FEM) value expressed in units of kilograms of fuel consumed per kilometer. The formula for calculating the FEM is:

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[1] The Convention on International Civil Aviation, drafted in 1944 by 54 nations to coordinate international air travel, is also known as the Chicago Convention. See ICAO (2006).

[2] The EPA and the FAA worked from 2009 to 2016 within the ICAO/Committee on Aviation Environmental Protection (CAEP) standard setting process on the development of the international airplane CO_2 emission standards

$$\text{Fuel efficiency metric value} = \frac{\left(\frac{1}{SAR}\right)_{avg}}{RGF^{0.24}}$$

Where:

SAR = specific air range

RGF = reference geometric factor.

SAR must be determined by either direct flight test measurements or using a performance model that is validated by actual SAR flight test data and approved by the FAA. Obtaining the RGF involves determining the internal surface area of the airplane. The procedures for determining both SAR and RGF are described in the rule and mirror those contained in ICAO Annex 16, Volume III, which is incorporated by reference (ICAO, 2018).

The proposed rule provides a table of limit values for the fuel efficiency metric reflecting the applicability of the standards (i.e., based on type, maximum take off mass (MTOM), and certification date). The metric values increase as a function of MTOM, with more stringent limits for new type designs reflecting greater ability to incorporate more fuel efficient technologies compared to models already in production (ICCT, 2018). The limits are also reflective of differences between larger commercial jets compared to smaller regional and business jets in that there may be fewer fuel efficiency technologies available for the smaller aircraft.

1.3 Scope of the Analysis

This document provides analysis of the costs to domestic airplane and airplane engine manufacturers affected by the proposed rule. In order to protect confidential business information (CBI), the FAA is providing only aggregated order of magnitude quantitative information. This analysis also provides qualitative description of the environmental benefits that may result from adopting the airplane fuel efficiency standard.

In proposing to adopt the EPA airplane emissions standards, which reflect the ICAO standards effective in January 2020, the FAA is not considering alternatives. However, the ICAO Committee on Aviation Environmental Protection (CAEP), which includes FAA representation, considered a large range of alternatives in its benefit cost analysis of the standard. The option selected by the CAEP – the ICAO standards – by design was considered technologically and economically achievable.

2.0 Need for the Regulation

As noted in Section 1.1, the Chicago Convention obligates member states to adopt domestic standards at least as stringent as ICAO standards and apply them to subject airplane and engine manufacturers. Other ICAO member states that certificate airplanes have adopted the standards.[3] The FAA is now proposing the certification requirements that will fulfill both its duty to enforce the ICAO standard adopted by the EPA and the obligation of the United States under the Chicago Convention.

In addition to the treaty obligation, the inability to certificate for fuel efficiency domestically would potentially disadvantage the industry in the United States. U.S. civil airplane manufacturers would need to utilize foreign certificating authorities for CO_2 emissions certification to sell their product internationally. Manufacturers would likely need to work closely with the foreign certificating authority, increasing certification costs.

Finally, although the environmental benefits may be attributable to multiple actions, the purpose of emissions standards is to limit emissions of CO_2 from aircraft. Aircraft emissions contribute to both local air quality degradation and global climate change. For technology following standards, which the ICAO airplane emissions standards represent, regulatory action addresses these externalities by setting limits at levels achievable using available emissions reducing technologies.[4]

Given the global market for airplanes, a coordinated approach on a worldwide basis is warranted. The proposed CO_2 emission standards are the result of a lengthy development process, and benefit cost analysis, that included significant participation by the FAA. The proposed rule is a crucial component to ensuring that the sought after benefits are realized.

[3] The European Union Aviation Safety Agency (EASA) supported the process to integrate the standards into European legislation and will implement them as of the applicability date of January 1, 2020 (EASA, European Environment Agency, and EUROCONTROL, 2019).
[4] In 2016, the EPA determined that greenhouse gas emissions from aircraft cause or contribute to pollution that may reasonably be anticipated to endanger public health and welfare (81 FR 54422).

3.0 Baseline for the Analysis

The baseline for analysis of the incremental costs and benefits of the proposed rule includes the existing regulations and current capabilities of U.S. aircraft manufacturers to meet the ICAO standards, and the environmental risks associated with aircraft emissions.

3.1 Existing Regulations

Pursuant to the Chicago Convention, the EPA and the FAA have been aligning aircraft emissions requirements with those promulgated by the ICAO. For example, in December of 2012, FAA amended (77 FR 76842) the emission standards for turbine engine powered airplanes to incorporate standards promulgated by the EPA in June of 2012 (77 FR 36342). The action revised the standards for oxides of nitrogen (NO_x) and test procedures for exhaust emissions based on two sets of limits established by the ICAO (and internationally applicable after December 2007 and November 2011). The standards apply to gas turbofan engines with maximum rated thrusts greater than 26.7 kiloNewton (kN) based on type certification date.

In 2017, the ICAO adopted standards for CO_2 emissions from airplanes which are contained in Volume III to Annex 16 of the Chicago Convention (Environmental Protection) (ICAO, 2017). The standards apply to new aircraft type design applications submitted on and after January 1, 2020 (January 1, 2023, for new type designs that have a MTOM of 60,000 kilograms or less and have 19 passenger seats or fewer). Manufacturers will no longer be able to produce aircraft that do not comply with the limits after January 1, 2028 (or introduce modifications without demonstrating compliance after January 1, 2023). The standards apply to civil subsonic jet airplanes having a maximum takeoff mass (MTOM) greater than 5,700 kilograms, and propeller-driven airplanes powered by turboprop engines having an MTOM greater than 8,618 kilograms.

The ICAO member states agreed upon a CO_2 metric system to measure aircraft fuel burn performance that would represent the CO_2 emissions produced by an aircraft.[5] The CO_2 metric system is based on three elements associated with aircraft technology and design: cruise point fuel burn performance; aircraft size; and aircraft weight. Based on this system, in developing the standard, ICAO aimed to reduce aircraft CO_2 emissions by encouraging the integration of fuel efficient technologies into aircraft design and development.

In December 2020, the EPA finalized regulations that match the ICAO standards by measuring the fuel efficiency of an aircraft and testing the airplane in flight. The airplane-specific characteristics of aerodynamics and weight affect fuel consumption, and ultimately CO_2 emissions. The standards are expressed in terms of reflect how far an airplane can fly on a single unit of fuel at the optimum cruise altitude and speed.

3.2 Existing Practices

The EPA stated that the ICAO/CAEP traditionally sets standards that are technology-following standards, meaning the CO_2 standards adopted reflect a level of emissions performance that is already achieved by some percentage of current in-production airplanes (EPA, 2020). The

[5] See the ICAO fact sheet, Aircraft CO_2 Emissions Standard Metric System, available at: https://www.icao.int/environmental-protection/Documents/CO2%20Metric%20System%20-%20Information%20Sheet.pdf.

ICAO/CAEP conducted detailed cost-benefit analyses of stringency options and determined in 2012 that all technology responses for its analysis would have to be based on technology that would be in common use. Therefore, the analysis that informed selection of technologically and economically feasible international standards reflected the emissions of airplanes that were in production, on order, or in development, including airplane types that would first enter into service by about 2020.

The EPA also conducted its own analysis and found that manufacturers will comply with the ICAO standards in the absence of U.S. regulations (EPA, 2020). The EPA compared the technologies and costs needed for airplane types to meet the standards to the improvements anticipated to occur under a business as usual scenario. The EPA relied on a detailed literature search, interviews with industry leaders, and modeling to estimate the cost of making modifications to in-production airplanes. The EPA used the ASCEND[6] Fleets database, among others, and the Project Interactive Analysis and Optimization (PIANO)[7] model of aircraft emissions and performance.

These findings are consistent with reporting following ICAO's adoption of the CO_2 standard. Boeing stated that it was being pushed by customer demand to reduce commercial jetliner emissions by investing in new, more efficient aircraft; improving operational performance of the in-service fleet; improving the efficiency of air traffic management and other infrastructure; and trying to increase the use of sustainable alternative fuels (McIntosh, 2017). Boeing stated that its new airplanes have been designed to meet or exceed the ICAO requirements. The 787 Dreamliner jet family reduces fuel use and CO_2 emissions by 20 to 25 percent compared to airplanes it replaces; the 737 Max will reduce fuel use and emissions by 20 percent compared to the older 737 Next Generation; and the 777X, with a first delivery expected in 2020, will be the world's largest and most fuel-efficient twin-engine jet (McIntosh, 2017).

In addition, ICAO based the certification test procedures on the existing practices of airplane manufacturers to measure airplane fuel burn (and to measure high-speed performance or cruise performance). Therefore, the EPA found that some manufacturers already have or would have airplane test data (or data from high performance modeling) that could be used to certificate their airplanes to the applicable standard (EPA, 2020). These data would already be part of the fuel burn or high-speed performance models. The relevant CO_2 or fuel burn data may already have been gathered during the airplane testing that the manufacturer conducts as part of certification.

3.3 Affected Entities

The FAA identified three U.S. manufacturers that would be affected by the proposed rule (Table 2). All three manufacturers are large businesses.[8]

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[6] FlightGlobal Fleets Analyzer, available at https://www.cirium.com/data-innovation/cirium-core/fleets-and-valuations/, also known as ASCEND database.

[7] Available at https://www.lissys.uk/.

[8] Owners or operators that modify an airplane that was not certificated to the proposed fuel efficiency standard may also need to comply with the rule when modifications are made. The FAA anticipates that very few owners or operators will undertake such modifications.

Table 2. Affected Entities

Company	Headquarters	Number of Employees[1]	Example Aircraft Manufactured
The Boeing Company	Chicago, IL	140,000	737, 747, 767, 777 and 787 families of airplanes; Boeing Business Jet range; Boeing 787-10 Dreamliner, the 737 MAX, and the 777X
Gulfstream Aerospace Corporation	Savannah, GA	13,300	G700, G650ER, G600, G500, G550, G280
Textron Incorporated	Providence, RI	33,000	Cessna and Beechcraft brands
1. Based on publically available sources.			

3.4 Environmental Risks

Carbon dioxide (CO_2) is a product of complete combustion of hydrocarbon fuels including gasoline, jet fuel, and diesel (FAA, 2015). The climatic impacts of aviation emissions are complex and include direct effects from CO_2 and water vapor emissions, the indirect effect resulting from changes in the distributions and concentrations of ozone (O_3) and methane (CH_4) from the emission of oxides of nitrogen (NO_x), the direct effects (and indirect effects on clouds) from emitted aerosols and aerosol precursors, and the climate effects associated with contrails and cirrus cloud formation (FAA, 2015). The FAA has also described the potential climate and social welfare impacts of these emissions in Aviation Emissions, Impacts & Mitigation: A Primer (FAA, 2015).

In 2016, the EPA found that found that elevated concentrations of greenhouse gases in the atmosphere endanger the public health and welfare of current and future generations (81 FR 54422 August 15, 2016). The EPA made this finding with respect to six well-mixed greenhouse gases, including CO_2, that together constitute the primary cause of climate change. The EPA also found that emissions of these gases from certain classes of engines used in certain aircraft are contributing to the air pollution that endangers the public health and welfare.

Airplane emissions of CO_2 are directly related to fuel use (FAA, 2015). Indeed, the ICAO approached CO_2 emissions from a fuel efficiency standpoint. Without fuel efficiency standards, the risk of technology backsliding in the future combines with the potential for increased population and demand for air travel to lead to increased emissions, with further detrimental impact. CO_2 emissions from commercial aviation in the United States totaled 134.2 teragrams[9] CO2 equivalent, which is 7 percent of CO_2 emissions from the U.S. transportation sector (EPA, 2021). Globally, U.S. aircraft greenhouse gas emissions represent 29 percent of all global aircraft GHG emissions and 0.5 percent of total global GHG emissions (EPA, 2020).

The baseline of airplane CO_2 emissions for measuring the incremental impact of the proposed rule has been affected by the public health emergency concerning the novel coronavirus disease (COVID-19). As the demand for air travel dropped off sharply, some airline retired older planes and in some cases entire fleet types, deferred aircraft deliveries, and sold aircraft and engines (Airlines for America, 2020). A January 2021 forecast predicts that global fleet growth from

[9] A teragram (Tg) is equal to 1 million metric tons.

2021 to 2031 will be markedly lower than projected prior to the pandemic (Oliver Wyman, 2021).[10] However, concerns about airplane CO_2 emissions are likely to resurface as the pandemic subsides and demand increases. Airplane manufacturers are moving ahead on projects to create commercial aircraft that do not rely solely on internal combustion engines, with Airbus announcing in September 2020 three concepts for the world's first zero-emissions aircraft (Oliver Wyman, 2021).

3.5 Uncertainties

Uncertainties regarding the baseline for the analysis primarily relate to the lingering impact of the COVID-19 public health emergency on the aviation industry. Lower forecast growth, and changes in fleet composition, including any delays in the adoption of fuel efficient airplane technologies, will impact CO_2 emissions.

[10] The impact on the aviation industry was just emerging, and the range of possible outcomes too wide, for incorporation into the FAA's 2020 to 2040 aviation forecast. FAA forecasts are available at: https://www.faa.gov/data_research/aviation/.

4.0 Benefits

The benefits of the proposed regulation are the monetized value of reductions in human health and environmental risks that may occur from improved fuel efficiency and reductions in airplane CO_2 emissions. This section provides qualitative analysis of these benefits.

4.1 CO_2 Emissions Reductions

In developing the CO_2 emissions standard, the ICAO, and the FAA through its participation, modeled the climate change and air quality impacts of a large number of potential stringency options (ICAO 2016a; 2016b). Climate change impacts include CO_2 and other effects (NO_X-O_3, NO_X-CH_4, contrails, aviation-induced cloudiness, sulfates, soot, H_2O) on globally-averaged surface temperature change. Air quality impacts modeled are the primary and secondary particulate matter concentrations ($PM_{2.5}$) impacts on the number of premature mortalities.

The modeling utilized an aircraft emissions inventory from 2006. Therefore, the analysis that informed option selection is not indicative of the incremental impact of the proposed rule as the baseline conditions have changed. The ICAO selected the stringency option for the standards to reflect a level of technological readiness at the time of applicability. For that reason, the baseline conditions of the U.S. aircraft fleet described in Section 2 already attaining the standards makes sense.

In adopting the standard, the EPA analyzed the benefits using a fleet inventory from 2015 (EPA, 2020). To develop this baseline, the EPA used the FAA 2015 operations data as the basis from which to project future fleet operations out to 2040. The EPA's Technical Support Document provides the details of the data, models, and assumptions, including key differences with those used by ICAO (the EPA developed a business as usual baseline scenario of continued annual fuel efficiency improvements compared to the constant technology assumption simplifying assumption used by ICAO).

The EPA estimated that there would not be reductions in fuel burn and CO_2 emissions beyond the business as usual baseline (EPA, 2020). The EPA considered this result reasonable because all airplanes will either meet the standards or be out of production by the time the standards take effect. The existing or expected fuel efficiency technologies from aircraft manufacturers were the basis of the selected option. Also, the EPA projected a baseline of continued improvement in aircraft fuel efficiency. Therefore, the EPA did not project either costs or benefits associated with adopting the standards (compared to business as usual).

With the proposed rule, the FAA is incorporating the EPA standards into certification requirements such that domestically certificated aircraft can be marketed internationally. Aircraft manufacturers have indicated that they do not have models for which they are seeking only domestic certification. Therefore, domestically certificated aircraft will maintain the fuel efficiency gains that have already been realized (i.e., antibacksliding). To the extent that actual certification flights confirm that current designs for new aircraft or continued production of existing aircraft meet the standard, there will be no incremental CO_2 reductions. To the extent that the proposed rule guards against backslides in fuel efficiency, or speeds the rate of fuel efficiency improvements, there would be incremental CO_2 reductions accompanying the needed mitigations.

4.2 Value of CO_2 Emissions Reductions

Reductions in CO_2 emissions are associated with reduced risks of global climate and local air quality improvements. To estimate emissions reductions, the FAA would need to know the changes resulting from aircraft design modifications or discontinued production of aircraft not meeting the standards that would not have occurred otherwise. Until manufacturers obtain all needed data to calculate the CO_2 metric such information is not available.

If changes in CO_2 emissions can be determined, modeling can translate reductions into benefits. For example, the FAA's Aviation Environmental Portfolio Management Tool for Impacts (APMT-I) estimates the environmental impacts of aircraft operations through changes in health and welfare endpoints for climate and air quality (Table 3). The AMPT-I climate model estimates monetary damages internally, as a function of a number of parameters, and includes short-lived (not well-mixed) climate forcers such as aviation-induced cloudiness and soot emissions. The AMPT-I air quality model values premature deaths using the value of statistical life (VSL).[11]

Table 3. APMT-I Effects Modeled

Impact Type	Effects Modeled	Primary Impact Metric
Climate	CO_2; Non-CO_2: NO_X-O_3, NO_X-CH_4, contrails, aviation-induced cloudiness, sulfates, soot, H_2O	Globally-averaged surface temperature change
Air quality	Primary and secondary particulate matter concentrations ($PM_{2.5}$)	Number of premature mortalities
Source: ICAO (2016a)		

Climate impacts from emissions reductions are also often valued using estimates of the social cost of carbon (SCC). The Interagency Working Group (IWG) on the Social Cost of Greenhouse Gases has developed interim estimates for use in regulatory analyses while undertaking a comprehensive update (IWG, 2021). As shown in Table 4 for CO_2, the estimated damages per metric ton of the pollutant emitted depend on the choice of discount rate (a lower discount rate results in a higher cost). The value also increases over time.

Table 4. Social Cost of CO_2 (2020$ per metric ton of CO_2)[1]

Emissions Year	5% Discount Rate Average	3% Discount Rate Average	2.5% Discount Rate Average	3% Discount Rate 95th Percentile
2020	14	51	76	152
2025	17	56	83	169
2030	19	62	89	187
2035	22	67	96	206
2040	25	73	103	225
2045	28	79	110	242
2050	32	85	116	260

[11] The VSL is approximately $11.6 million (DOT, 2021). For example, a reduction in the risk of one fatality per year generates annual benefits of approximately $11.6 million per year.

Table 4. Social Cost of CO_2 (2020$ per metric ton of CO_2)[1]

Emissions Year	5% Discount Rate Average	3% Discount Rate Average	2.5% Discount Rate Average	3% Discount Rate 95th Percentile
Source: (IWG, 2021) 1. Values are the average across models and socioeconomic emissions scenarios for each of three discount rates (2.5%, 3%, and 5%), plus a fourth value, selected as the 95th percentile of estimates based on a 3% discount rate.				

4.4 Uncertainties

There are uncertainties associated with analysis of benefits from the proposed rule. For example, the ICAO standards establish an internationally agreed-upon way of comparing aircraft fuel efficiency, which could increase competitiveness in market with respect to fuel efficiency. As such, reductions in airplane CO_2 emission could occur at a rate faster than under a business as usual baseline.

The impact of the public health emergency concerning the novel coronavirus disease (COVID-19) on airplane fleet composition is also uncertain. The downturn in industry conditions has resulted in some airlines retiring older aircraft, and in some cases entire fleet types (Airlines for America, 2020). These retirements could reduce the baseline emissions forecast in the short term, and reduce the incremental impact of the proposed rule.

5.0 Costs

This section describes the estimation of the costs associated with the proposed rule, including the data and information available for the analysis, methods, and uncertainties.

5.1 Data

The FAA requested data from the three airplane manufacturers that would be affected by the rule as proposed on the costs associated with CO_2 emissions certification and the potential differences in these costs with and without the proposed rule. This section describes the results of that outreach.[12]

Certification Project Tasks

Certification tasks will vary greatly depending on the stage of the airplane development process (e.g., new type certificate, supplemental type certificate). Additionally, initial certifications may be more involved than subsequent ones due to process familiarity and the ability to reuse data. Table 5 shows general tasks that may be involved in certifying a model airplane to meet the CO_2 emissions standard.

Table 5. CO_2 Emissions Standards Certification Project Tasks

Task	Description
Project management/ODA administration	Managing program activities, communicating, coordinating, and ODA communicating with aviation authorities.
Certification plan	Writing the certification plan, including coordination with all relevant disciplines, internal review, approval routing, and submittal.
Flight test plan	Writing the certification flight test plan, including coordination with all relevant disciplines, technical and safety reviews, approval routing, and submittal.
Conformity	Coordinating and drafting the discipline-specific conformity requests, routing and approvals, inspection, and disposition of any conformity-related unsatisfactory. Conformity will be required for aerodynamics, structures, flight controls, powerplant, engine controls, fuel systems, instrumentation, and possibly others.
Type inspection authorization	Coordinating, drafting, and routing the type inspection authorization paperwork.
Instrumentation system	Determining the accuracy of the portions of the instrumentation system relevant to CO_2 certification testing, related analysis, and documentation.
Flight testing	Preparing for test, reviewing test plan, briefing, conducting preflight activities (mechanic, instrumentation, avionics tech, quality/inspection, ODA release, fuel sample collection, weigh and balance on scales), conducting test, conducting post flight debrief, ground station data processing, and preparing flight report.
Determination/documentation of RGF	Reviewing drawings or 3D models to determine RGF, and recording in official company documentation.
ODA = Organization Designation Authorization RGF = Reference Geometric Factor	

[12] The individual responses are manufacturer Confidential Business Information.

There may also be costs associated with conducting the certification through foreign authorities (i.e., in the absence of the proposed rule), depending on how these costs differ from those of certificating in the United States. Aside from differentials in certification fees,[13] there may be costs associated with travel and minor procedural or paperwork differences incurred by working through a foreign certification authority. Certification with a foreign authority (compared to domestic) could also increase costs due to additional engineering logistics/coordination.

Certification Projects

Airplane manufacturers will incur costs for initial type certification to demonstrate compliance with the fuel efficiency standards, and when certain modifications are made, including improvements that would result in a lower FEM value. (Lower metric values are considered as increasing the market competitiveness of the airplane.) Manufacturers may budget for one or more certification projects at a time, and have used experience with past certification projects in providing cost estimates to FAA. Not included in the estimates are any costs associated with modifications to current or future designs necessary to meet the standards (which may not be known until the manufacturer applies for certification).

In public comments to the EPA's proposal to adopt the ICAO standard, Boeing estimated that it could need to certificate 19 airframe/engine combinations to the in-production requirements before 2028, while Cessna and Gulfstream estimated that together they could need to certificate approximately 14 airframe/engine combinations within the same timeframe (Boeing, 2020; p. 22).

5.2 Method

To estimate costs, the FAA used the information provided by the airplane manufacturers to construct a timeline of when these costs would be incurred over the next 10 years (starting in 2022). The FAA calculated both the cost of certificating to the fuel efficiency standard, which manufacturers will incur regardless of the proposed rule, and the cost savings attributable to the proposed rule from being able to certificate domestically.

To protect the Confidential Business Information (CBI) provided by the manufacturers, the FAA is not presenting the unit cost estimates or other detailed breakdown of the estimated costs. However, the FAA provides aggregated information to the extent possible.

5.3 Results

Based on airplane manufacturers' past experience and projections, annualized costs associated with certifying airplanes to the fuel efficiency standard in the United States may be approximately $800,000 using a 3 percent discount rate, or $1.4 million using a 7 percent discount rate. The present value over a 10-year period would be approximately $7.0 million using 3 percent discount rate and $9.8 million using a 7 percent discount rates. These estimates do not include the costs of any mitigations that may be needed. Because the ICAO set the

[13] Fees are transfer payments and not included in social costs. However, transfers to from the United States to other nations should be included as costs.

standard to be technology following, U.S. manufacturers may already be in compliance. However, the need for mitigations may not be known for certain until an application for certification is filed.

In the absence of the proposed rule, manufacturers would need to conduct the certification activity through foreign certificating authorities. Airplane manufacturers' estimates of the impact of such circumstances on costs vary and reflect as yet unknowns, but suggest annualized incremental costs of $0.3 million using a 3 percent discount rate, and $0.4 million using a 7 percent discount rate. The present value over 10 years would be $2.2 million using a 3 percent discount rate and $2.6 million using a 7 percent discount rate. The proposed rule avoids these incremental certification costs thus generating cost savings (Table 6).

Table 6. Incremental Impact of Proposed Rule (Millions 2020$)[1]

Annualized Costs (3% Discount Rate)	Present Value over 10 Years (3% Discount Rate)	Annualized Costs (7% Discount Rate)	Present Value over 10 Years (7% Discount Rate)
-$0.4	-$3.1	-$0.4	-$2.6
1. Represents the avoided costs of certifying to the ICAO CO_2 airplane emissions standards through foreign certification authorities compared to through the FAA under the proposed rule.			

5.4 Uncertainties

There are uncertainties with respect to the timing for rule implementation. As a result, market demand may speed up the schedule for certification, particularly if specific countries or local airports impose restrictions or tariffs on operations based on CO_2 metric values. The present value of costs incurred sooner in the analysis period is higher since discounting future years has the effect of reducing costs.

6.0 Summary

The analyses conducted by the ICAO, with FAA participation, indicate that the airplane CO_2 emissions standards will generate climate change and air quality (human health) benefits globally, including in the United States, through use of fuel efficient airplane technologies (ICAO 2016a; 2016b). These benefits will be achieved in the baseline, since U.S. manufacturers, who operate in a global marketplace, will need to certificate airplanes to meet the international standards even in the absence of the proposed domestic rule. Manufacturers did not identify incremental environmental and human health benefits associated with the proposed rule.

The proposed rule may result in annualized cost savings of $0.4 million using a 3 percent discount rate, and $0.4 million using a 7 percent discount rate. The present value over 10 years would be $3.1 million using a 3 percent discount rate and $2.6 million using a 7 percent discount rate. These savings represent avoided costs associated with having to certify airplanes to the CO_2 emissions standards through foreign certificating authorities.

There are a number of uncertainties associated with these results. With respect to benefits, there is potential for greater fuel efficiency gains being a competitive advantage for manufacturers. At the same time, the impact of the public health emergency concerning the novel coronavirus disease (COVID-19) on the industry is uncertain. Changes in airplane fleets could affect the estimated baseline, as well as benefits and costs. The timing for rule implementation may also be an important factor in that market demand may speed up manufacturers' schedules for certification given the original applicability dates in the ICAO standard.

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Appendix. ICAO Airplane CO_2 Emissions Standard Certification Outreach Questions

Note: FAA will not share any Confidential Business Information and will aggregate data such that it will not identify the provider of the information.

1. Do you produce any airplanes that would be subject to the ICAO airplane CO_2 standard internationally but which you do not market abroad (i.e., you would not need to certify in the absence of an FAA CO_2 certification standard)? Which ones?

2. What range of costs do you anticipate to incur for certification of compliance with the ICAO airplane CO_2 standard?
    a. What does this estimate include (e.g., new equipment or tests)? Do you have a breakout by component?
    b. When will you incur these costs (timeframe)? Can you provide the estimates by year?
    c. What is the difference in this range to obtain certification in the United States versus from another country and what does it reflect (e.g., locational factors)?

3. What other impacts do you anticipate from being able to certify compliance with the ICAO airplane CO_2 standard in the United States versus from a foreign country?
    a. Environmental benefits?
    b. Business or industry impacts?
    c. Other?